Management Summary

UCRL-AR-122289 Rev. 2

Environmental Restoration
at

Lawrence Livermore National Laboratory
Livermore Site
Livermore, California

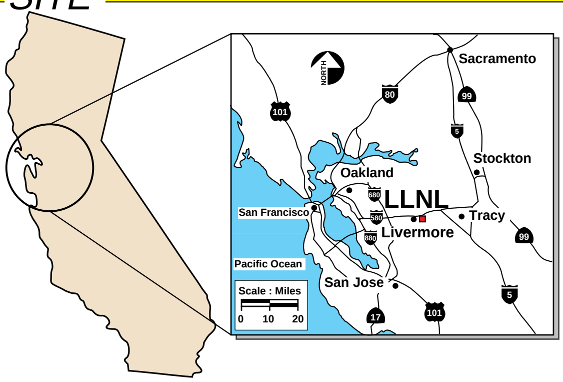
U.S. Department of Energy

July 1996

Work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

Management Summary

SITE



This management summary describes the status of environmental cleanup at Lawrence Livermore National Laboratory (LLNL) Livermore site, Livermore, California. Optimized hydraulic control, source removal, and advanced technologies are being used to clean up ground water contaminated with volatile organic compounds (VOCs), fuel hydrocarbons (FHCs) and chromium by using a network of treatment facilities employing ultraviolet (UV)/oxidation, air stripping, ion exchange, and granular activated carbon (GAC) technologies. Initial treatment began in 1989 and additional capacity is being phased in through an ongoing evaluation process. Soil vapor extraction (SVE) is the primary technology being employed to clean up the vadose zone at LLNL source areas.

SITE CHARACTERISTICS

Site History/Release Characteristics

• The 800-acre LLNL site was converted from agricultural use into a flight training base and aircraft assembly and repair facility by the Navy in 1942. In 1951, the Atomic Energy Commission converted the site into a weapons design and basic physics research laboratory. Later site missions have included programs in biomedicine, energy, lasers, magnetic fusion energy, and environmental science.
• Initial releases of hazardous materials occurred in the mid to late 1940s. There is also evidence that subsequent localized spills, leaking tanks and impoundments, process cooling water and landfills released VOCs, FHCs, chromium and tritium to sediments and ground water, primarily from 14 major areas of concern.
• In 1983, VOCs were detected by LLNL in domestic water supply wells west of the site. A regulatory order to investigate ground water quality was issued by the state in 1984 and ultimately lead to investigation of over 350 potential release sites.
• Bottled drinking water was supplied to nearby residents beginning in 1983 and all affected supply wells were permanently sealed between 1985 and 1989 by LLNL. Waste pits and a landfill were excavated and backfilled in 1982/83 and 1984, respectively. The LLNL Livermore site was added to the National Priorities List in 1987.

Site Conditions

• The ground surface slopes gently to the northwest changing in elevation from 670 ft above mean sea level (MSL) to 570 ft above MSL from the southeast to northwest corners. Two intermittent streams, the Arroyo Seco and the Arroyo Las Positas, traverse the area.
• Climate is semiarid with annual precipitation about 14 inches/year.
• Land north and south of the site is zoned for industrial use, high-density residential areas are west of the site, and east of the site is primarily agricultural land.
• Municipal water supply wells in downtown Livermore approximately 1.6 miles away from the contaminant plume are the primary drinking water source for over 10,000 of Livermore's 60,000 plus residents.

Nature and Extent of Contaminants

VOCs: • VOCs are found in saturated sediments underlying approximately 85% of the Livermore Site and occupy an area of about 1.4 square miles. The VOC ground water plumes vary between 10 and 100 ft in thickness and are generally found above 200 ft in depth.
• TCE is the predominant VOC, with maximum concentrations on the order of 5000 ppb; PCE, 1,1-DCE, 1,2-DCA, 1,1,1-TCA, carbon tetrachloride, chloroform, Freon 113 and Freon 11 are also frequently present.
• VOCs are also found in the vadose zone in several areas that are impacting ground water.

FHCs: • Fuel hydrocarbons, including free product, are present in saturated sediments associated with previous gasoline releases near the southern boundary of the site.
• Dynamic underground steam stripping, electrical heating, and ground water and vapor extraction have removed approximately 10,000 gallons of gasoline product from the subsurface.
• Residual fuel hydrocarbons are still present up to 2 ppm in ground water within 300 ft. of the source and up to approximately 10,000 ppm in soils at one location.
• Remediation by natural bioattenuation of hydrocarbon compounds appears promising and is currently under active investigation.

Metals: • Metals from both natural conditions and facility activities exceed drinking water standards in several locations. Chromium, naturally occurring and used as a corrosion inhibitor in cooling towers in the past, is found in concentrations up to 160 ppb in ground water.

Radiological Parameters: • Ground water in the few wells where tritium is detected is expected to decay below federal and state drinking water standards before the water migrates offsite if no remediation was conducted.

Contaminants of Concern

VOCs:

Trichloroethylene	(TCE)
Perchloroethylene	(PCE)
1,1 & 1,2-Dichoroethylene	(DCE)
1,1 & 1,2-Dichloroethane	(DCA)
Carbon tetrachloride	(CCl_4)
1,1,1-Trichloroethane	(TCA)
Chloroform	(HCl_3)

FHCs:

Benzene	(B)
Toluene	(T)
Ethylbenzene	(E)
Xylenes	(X)
Ethylene dibromide	(EDB)

Metals:

Chromium	(Cr)
Trivalent chromium	(Cr^{3+})
Hexavalent Chromium	(Cr^{6+})

Radiological Parameters:

Tritium	(H^3)

Remediation Strategy

The overall long-term environmental remediation strategy for the LLNL Livermore Site uses ground water extraction and treatment that is based on an hydraulic control philosophy including:

- detailed site characterization, including hydrostratigraphic unit (HSU) analysis
- validated modeling, and decision support
- phased implementation of remediation,
- directed extraction and injection; and
- adaptive time-managed pumping.

This unique approach will:

- enable testing and optimization of extraction, injection and treatment systems, their efficiencies, and hydraulic capture and contaminant removal prior to full-scale implementation;
- employ dynamic management of wellfields and optimizing of cleanup through field monitoring and modeling; and
- continue to involve and inform the stakeholders to ensure continued regulatory and community acceptance.

Dynamic management of the wellfield involves operation of individual wells either continuously, intermittently, or not at all depending upon the results of field monitoring and the estimates of models and optimization routines:

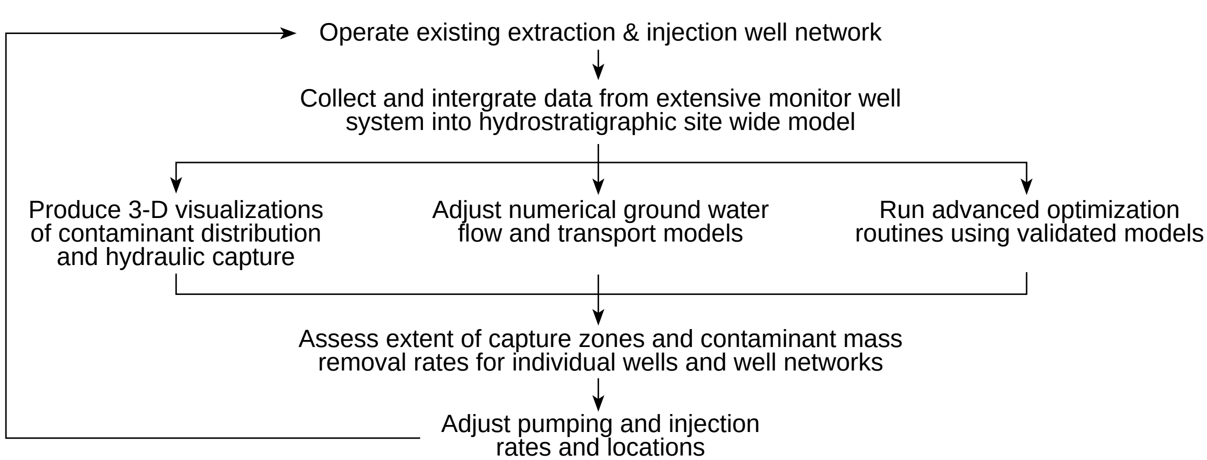
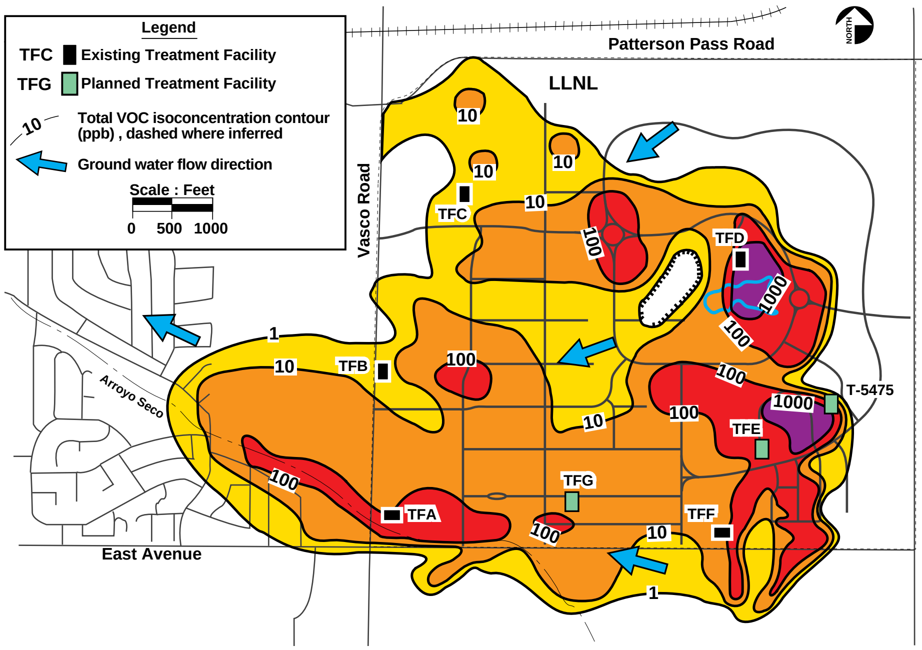


Figure 1. RI/FS map from 1990, showing the distribution of VOCs in ground water and the location of ground water treatment facilities at LLNL. As shown in Figures 5 and 7, VOC concentrations have decreased dramatically along the western downgradient margin of the site since ground water extraction began in 1989.



Currently there are six ground water extraction/treatment facilities and one vapor extraction system operating at the site (Figure 1). Treatment Facility A (TFA) and Treatment Facility B (TFB) have been operating nearly continuously since 1989 and 1990, respectively, and have attained hydraulic control and significant mass removal from the southwestern offsite plumes. With the addition of an expanded extraction system at Treatment Facility C (TFC) in FY96, hydraulic control of the entire western perimeter is anticipated. With the recent startup of Treatment Facility G-1 (TFG) and extraction from a deeper plume at Treatment Facility F (TFF), the southern perimeter should be hydraulically controlled.

By the end of FY96, we anticipate that full hydraulic control of the distal plumes will be achieved and an aggressive program to remediate the source areas will be implemented and expanded. Continued vapor extraction at Treatment Facility 518 should result in cleanup of the southern perimeter vadose zone sources in less than five years.

Three-dimensional (3-D) computer modeling (using the model CFEST) indicates that ground water cleanup of the distal plumes to 25 ppb can be accomplished in 10 to 15 years after complete buildout of the extraction/treatment systems. Complete buildout is expected by the year 2003. By extrapolating the distal area 3-D modeling results to the source areas, we anticipate that ground water cleanup of the source areas to 25 ppb might be accomplished in approximately 23 years after complete buildout of the extraction/treatment systems. Additional modeling of the source areas is needed to confirm this extrapolation. We envision that negotiations with the regulatory agencies within the next decade could result in relaxation of our current ground water cleanup goals.

The ground water cleanup at the LLNL Livermore Site will be accelerated by continuing to utilize advanced pump and treat techniques within the distal portions of the contaminant plumes. As the ground water is remediated to a negotiated cleanup level, the active wellfields will contract toward the source areas and only a small number of wells will remain pumping immediately downgradient of the source areas to prevent further downgradient contaminant transport. Simultaneously with the cleanup of the distal portions of the plumes, the source areas will be aggressively remediated by ground water pumping, vapor extraction and a series of new in situ destruction technologies including hydrous pyrolysis, bioremediation, and abiotic destruction. These in situ technologies are currently being pursued under the Accelerated Cleanup Initiative (jointly funded by DOE's EM40 and EM50 organizations and LLNL) and could significantly reduce the estimated time to cleanup.

This cleanup strategy can be accomplished assuming funding at the FY98 Planning Case Level of $14.5M for the Livermore Site.

STATUS OF CLEANUP

Contaminant Locations and Hydrogeologic Profiles

Remedial investigation activities at LLNL Livermore site involved review of over 350 potential release sites which were incorporated within 14 areas of concern. The source investigation methodology involved review of historical information, sample collection and drilling of over 800 boreholes. The site hydrogeology was characterized from:

- field borehole logs
- borehole geophysical logs
- hydraulic test data (over 300 tests were conducted over a 4 year investigation period)
- sediment and water chemistry
- subsurface data from other investigations, including seismic and soil vapor surveys

This data was used to develop a contaminant hydrogeological model of the site (Figure 2).

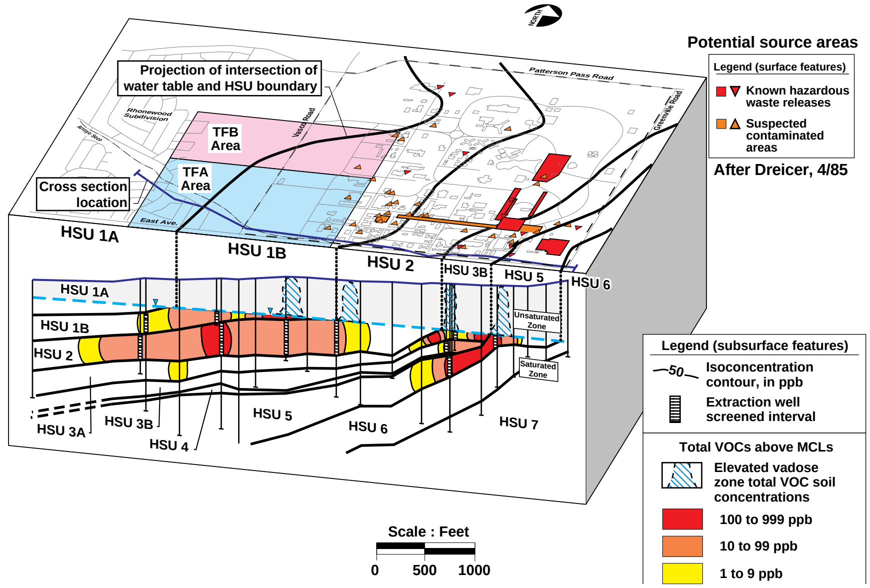


Figure 2. Block diagram showing the current distribution of VOCs within individual hydrostratigraphic units (HSUs) beneath the site. This level of mapping was required in order to implement cost-effective ground water clean up at the LLNL Livermore site.

Status of Cleanup Highlights

- The lateral and vertical extent of the primary VOC plumes have been characterized, mapped in detail, and related to individual source areas (Figure 2).
- Individual contaminant plumes have been targeted for cleanup using adaptive pump and treat and innovative technologies at each Treatment Facility area (Figures 3, 5, and 7).
- Extraction well locations have been optimized for VOC mass removal and hydraulic control to inhibit migration of plumes offsite (Figures 4-7).
- Time series maps show successful hydraulic capture and cleanup of individual plumes on the down-gradient western margin of the LLNL Livermore site (Figures 5 and 7).

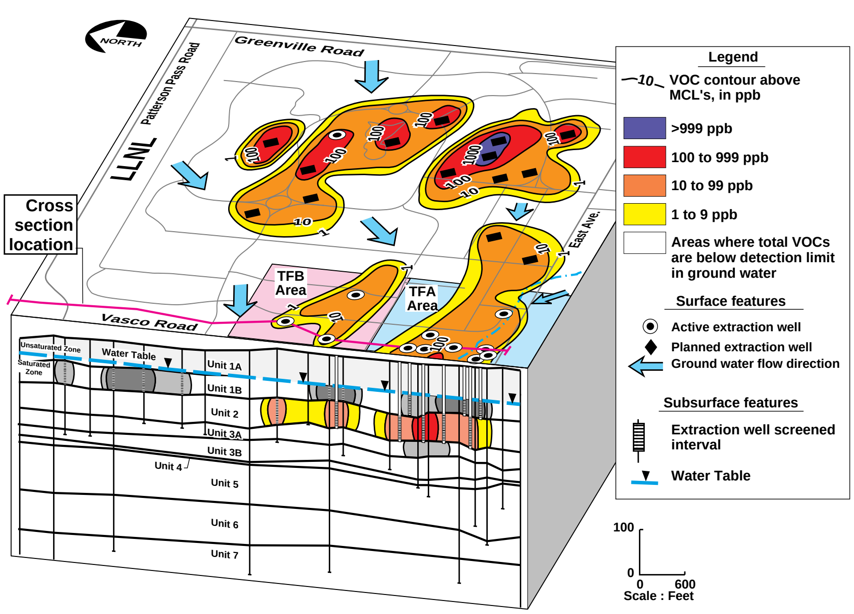
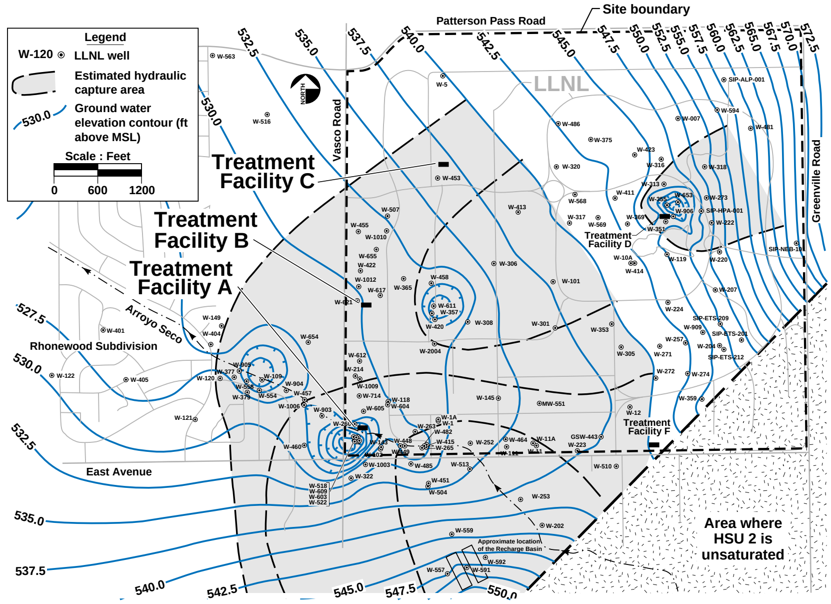


Figure 3. Block diagram showing a map view and cross-sectional view of contaminant distribution in hydrostratigraphic unit HSU-2. Extraction wells have been located and designed for maximum mass removal and hydraulic capture of individual VOC plumes within each hydrostratigraphic unit.

Figure 4. 1995 ground water elevation map showing hydraulic capture areas (shaded areas) which encompass onsite and off-site VOC plumes in HSU-2 (see Figure 5) along the western margin of the site.



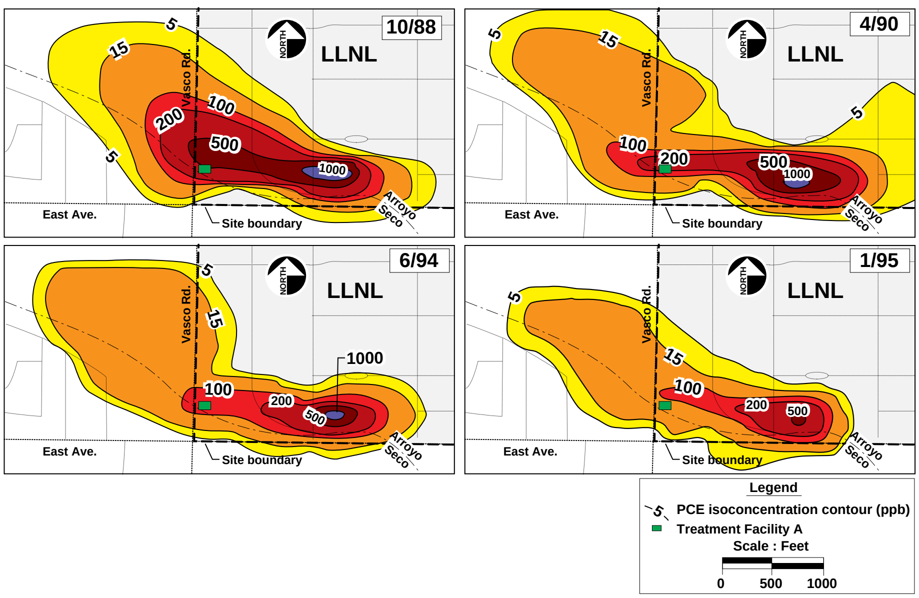


Figure 5. VOC plume maps in HSU-2 near TFA show a dramatic decrease in concentrations of PCE with time in response to ground water extraction and treatment (Figure 11). New HSU-2 extraction wells will expand the hydraulic capture area encompass the western margin of the plume and will target the residual concentrations above 100 ppb.

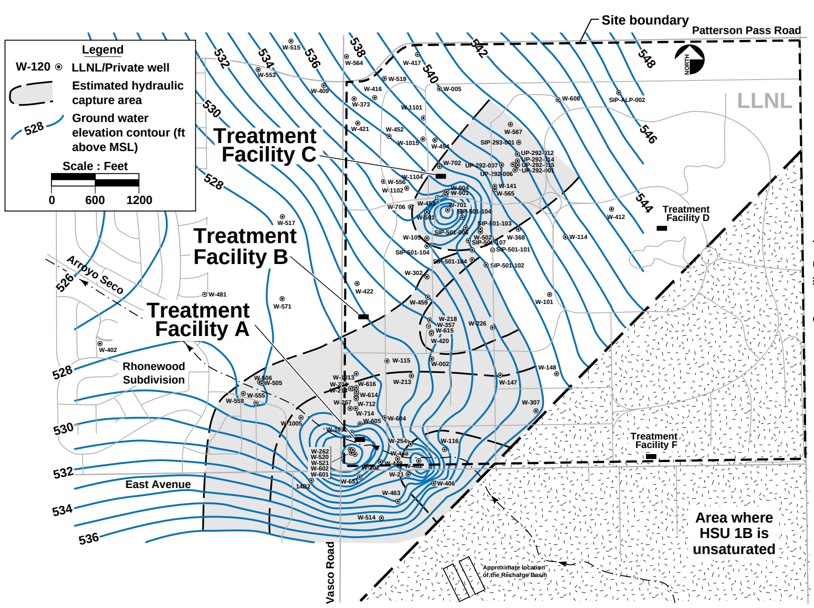


Figure 6. 1995 ground water elevation map showing hydraulic capture areas which encompass onsite and offsite VOC plumes within HSU-1B. As additional ground water extraction wells come on line at TFA, B, and C, the hydraulic capture area (shaded area) on the western margin of the site is expected to increase dramatically.

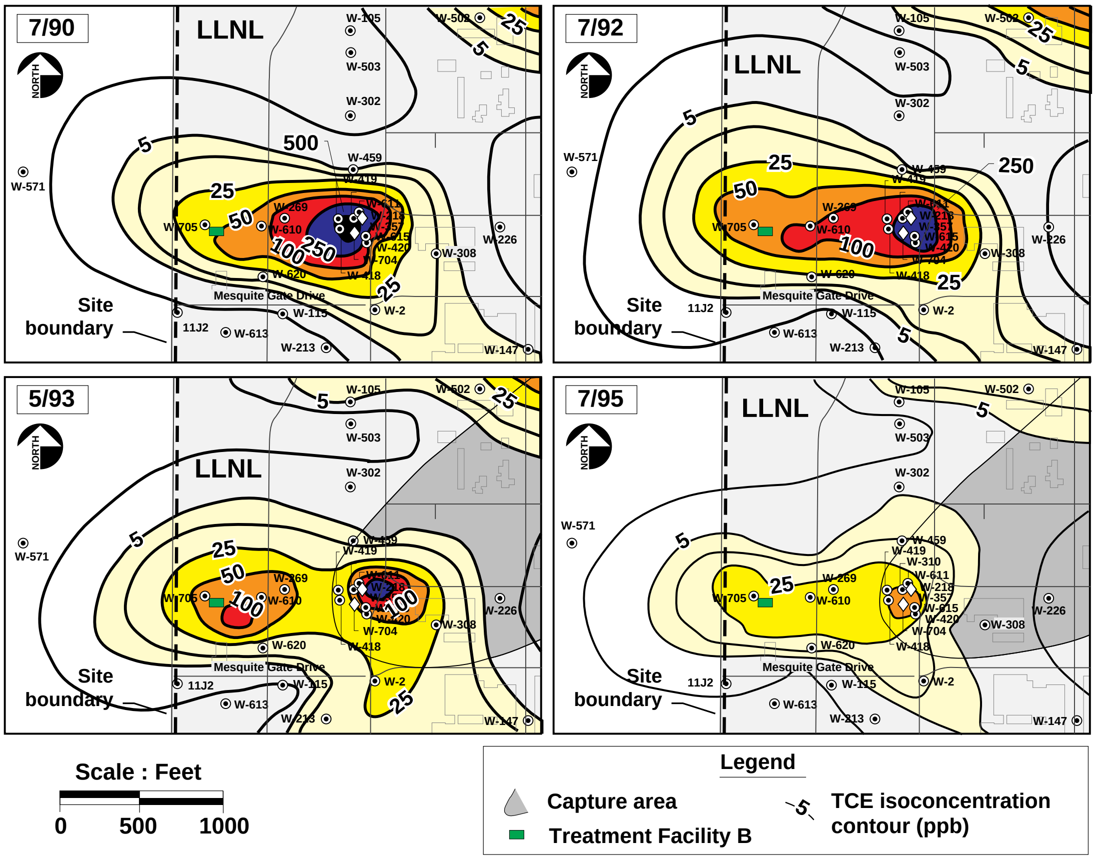


Figure 7. VOC plume maps in HSU-1B at TFB show a dramatic decrease of concentrations over time in response to ground water extraction and treatment (Figure 12). The shaded area represents the hydraulic capture area created by TFB extraction wells pumping from HSU-1B. New extraction wells to the west which began pumping in September 1995 will expand this capture area and further accelerate cleanup.

HYDROSTRATIGRAPHIC CHARACTERIZATION

Site Characterization Methodology

Initial remedial investigation efforts at LLNL Livermore site using a depth-sampling technique developed at LLNL led to an understanding of subsurface conditions and contaminant distributions. Geologic cross-sections (see Figure 8) showing locations of contaminants were constructed using these data. More recent site characterization activities have focused upon the development of a comprehensive hydrostratigraphic characterization of the site through application of a systematic methodology (Figure 9). This methodology entails:

1 *Evaluating Independent Data Sets*
- hydraulic test results & water levels
- geophysical well logs
- geologic core descriptions
- chemical analyses of soil & ground water
- high resolution seismic reflection

2 *Defining Hydrostratigraphy*

3 *Generating Informational Displays*
- hydrostratigraphic cross-sections
- hydraulic communication maps
- subsurface structure maps
- isopach maps
- potentiometric surface maps
- isoconcentration maps

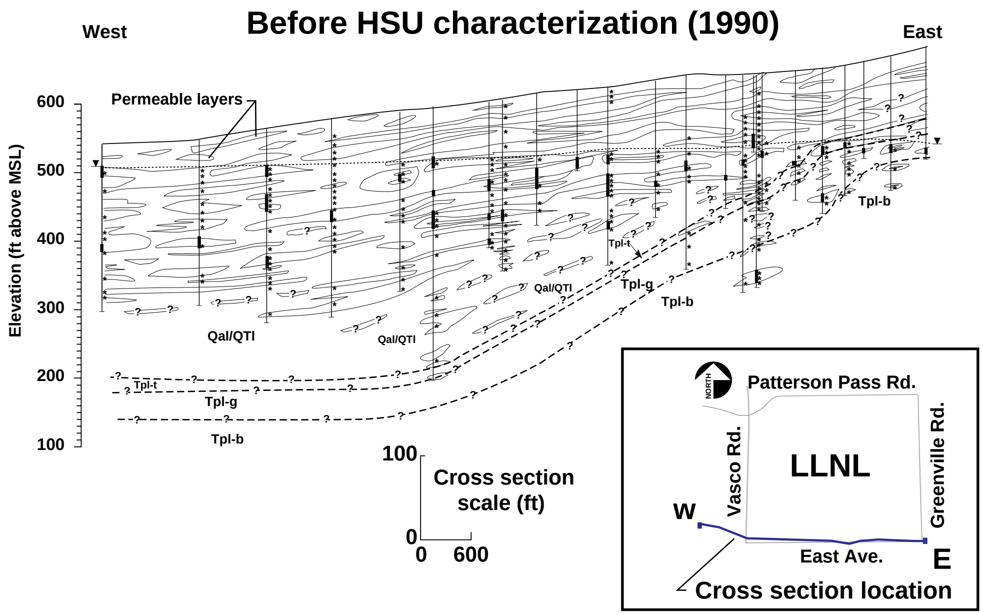
4 *Developing of a Conceptual Model for 3-D Fate and Transport Simulations*

5 *Applying Results to Site Cleanup*

Overall, 4 lithologic units (not shown below) and 7 hydrostratigraphic units (shown below) have been identified.

This methodology provides information for optimizing the location of extraction wells to:
- maximize contaminant mass removal rates,
- hydraulically control plumes, and
- optimize extraction well locations to target individual VOC plumes

Figure 8. Typical hydrogeologic cross-section prepared for the LLNL Remedial Investigation report in 1990. While the cross-section accurately portrays the heterogeneity of the subsurface, it does not depict the hydraulic communication between permeable layers containing VOCs beneath the site. Additional characterization was required to implement cost-effective cleanup at the site. Compare with Figure 9.



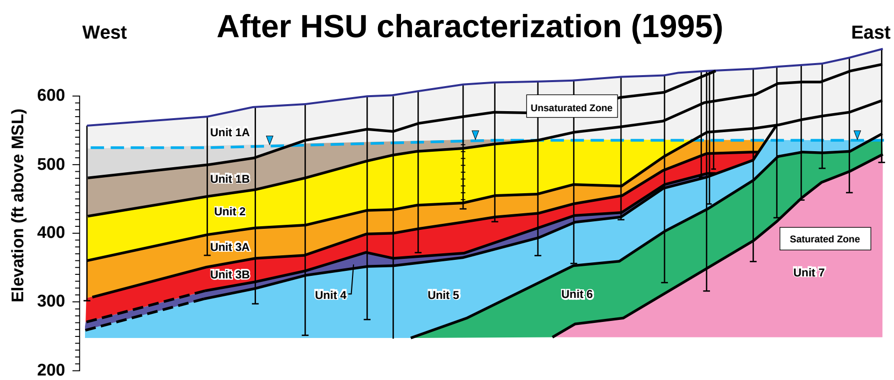


Figure 9. Hydrostratigraphic cross-section constructed using the methodology described above. The heterogeneous sequence depicted in Figure 8 has been subdivided into hydrostratigraphic units whose constituent permeable layers are hydraulically interconnected. This eliminates the need to complete extraction wells in each individual permeable unit containing VOCs.

REMEDIATION PERFORMANCE

Remediation History

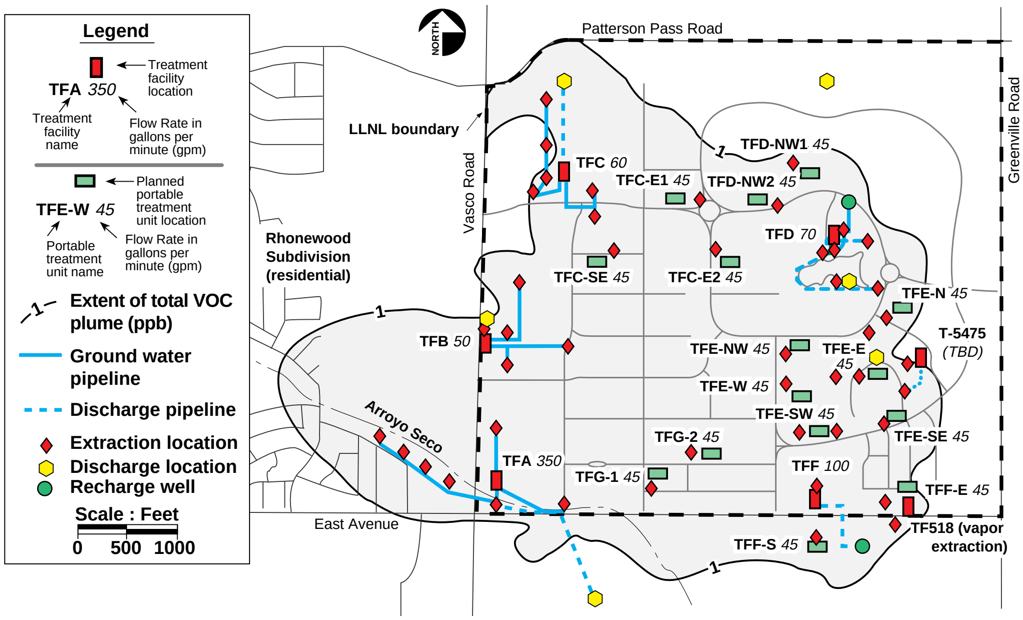
The LLNL Livermore site ground water treatment program is currently being implemented. Treatment facilities A,B,C, D, and F have operated with some of the planned extraction wells since their startup. As the wellfields are emplaced, hydraulic control and mass removal are realized. Vapor Treatment Facility 518 (TF518) began operation in September 1995. Treatment facility performance information gathered to date is presented in the following "Performance" subsections.

Performance Criteria

The environmental cleanup at the LLNL Livermore site is designed to satisfy numerous chemical-specific, location-specific and action-specific requirements. The driving force for cleanup is Federal and California Maximum Contaminant Levels (MCLs) for drinking water. The MCL for the primary contaminants, PCE and TCE, is 5 ppb. The project is also designed to:

- Prevent migration of contaminated ground water to nearby offsite water supply wells.
- Cleanup offsite plume components.
- Achieve cleanup goals in minimum time and cost.

Figure 10. LLNL site map showing treatment facilities, extraction locations, and associated pipelines. Portable Treatment Units (PTUs) supplement the treatment facilities and will be deployed as needed.



The extraction well and treatment facility network is a combination of fixed treatment facilities (TFA, TFB, TFC, TFD and TFF) with pipelines to extraction wells, and portable treatment units (PTU) near extraction wells.

Fixed treatment facilities are used for hydraulic capture of the plume at the border of the site. PTUs are used to remediate areas near sources and can be moved to adapt to the changing plume. Treated ground water is discharged to a recharge basin, recharge well or to drainage ditches which empty into a local creek (Arroyo Las Positas). Treated ground water can also be used for irrigation or facility cooling systems.

Existing fixed treatment facilities TFA, TFB, TFC, TFD and TFF are constructed with additional pipelines to be added if needed. A PTU has been constructed for hydraulic testing and a second PTU will be activated in April 1996 as TFG-1. Soil vapor extraction systems are in place at TFF and TF518 and planned for the Trailer 5475 area.

TFG will consist of two PTUs designated PTU-1 and PTU-2. LLNL is negotiating with the regulatory agencies to build TFE as a series of PTUs, shown on Figure 10, rather than a large fixed treatment facility with pipelines. PTUs will be added to TFC and TFD instead of pipelines, which will reduce cost and improve performance.

Treatment System Overview

Treatment facility	Primary target contaminants	Startup date	Total design flow rate in gpm	Treatment
TFA	PCE, 1,1-DCE	1989	350	UV/Oxidation → Diffuse Aeration with GAC Treatment of Offgas
TFB	TCE, CCl_4, PCE	1990	50	UV/Oxidation → Diffuse Aeration with GAC Treatment of Offgas
TFE	TCE, PCE, (Possibly Cr)	1999	70	UV/Oxidation → Diffuse Aeration with GAC Treatment of Offgas
TFC	TCE, Cr, Freon 113, PCE	1993	60	Air Stripping by Diffuse Aeration → GAC Treatment of Offgas; Ion Exchange Treatment for metels
TFD	TCE, Cr, Ni	1994	70	Air Stripping by Diffuse Aeration → GAC Treatment of Offgas; Ion Exchange Treatment for metels
TFE PTU	TCE, Cr	1996	45*	Air Stripping by Diffuse Aeration → GAC Treatment of Offgas; Ion Exchange Treatment for metels
TFG PTU	TCE, Cr	1996	45*	Air Stripping by Diffuse Aeration → GAC Treatment of Offgas; Ion Exchange Treatment for metels
TFF	FHCs, 1,2-DCA, TCE	1993	100	Oil/Water Separation → UV/Oxidation → Diffuse Aeration with GAC Treatment of Offgas

- Treatment Facility G, scheduled for initial operation in 1996, will be installed as 2 separate PTUs to treat VOC contaminated ground water at a total rate of 90 gpm by air stripping followed by GAC.
- The Trailer 5475 facility is scheduled for design in 1997.

* Flowrate per PTU.

Legend

Treatment facility → TFA	PCE 1,1-DCE ← Primary target contaminants
Startup date → 1989	350 ← Total design flow rate in gpm

Treatment Performance

Treatment Facility Design Concentrations

	Design Average Influent Concentrations [ppb]								***Treated Effluent Discharge Limits [ppb]***	
	TFA	***TFB***	***TFC***	***TFD***	***TFE***	***TFF***	***TFG-1***	***TFG-2***	***NPDES***	***LWRP***
TCE	7	300	20	875	860	200	38	17	-	-
PCE	280	40	5	28	60	10	13	22	4	-
1,1-DCE	12	10	2	11	20	10	11	1	-	-
1,2-DCE (cis&trans)	4	3	-	1	1	-	-	2	-	-
1,1,1-TCA	5	1	-	-	-	3	3	-	-	-
1,1-DCA	5	5	-	1	-	-	-	-	-	-
1,2-DCA	-	1	-	20	2	130	-	-	-	-
Chloroform	10	10	3	5	9	20	15	4	-	-
CCl_4	-	2	-	20	3	10	7	3	-	-
Freon 113	5	10	100	1	8	10	7	3	-	-
Freon 11	-	-	-	148	-	-	-	-	-	-
EDB	-	-	-	-	-	10	-	-	0.02	-
Benzene	-	-	-	-	-	20,000	-	-	0.7	-
BTEX	-	-	-	-	-	65,000	-	-	-	250
Total VOCs	328	382	130	1,110	963	403	99	50	5	1,000
Lead	-	-	-	-	-	30	-	-	5.6	200
Cr^{6+}	-	20	30	11	4	-	21	9	11	-
Total Cr	-	20	30	11	4	-	21	9	50	620

NOTE: "-" = not part of design basis; negligible anticipated influent; NPDES = National Pollutiant Discharge Elimination System permit; LWRP = Livermore Water Reclamation Plant requirement.

Operational/Treatment Performance

Effects on Plume

Current agreements specify that all treatment facilities will be operated until *in situ* ground water VOC concentrations are below MCLs for 2 years. Final closure will be defined in the Compliance Monitoring Plan.

Influent Contaminant Concentrations vs Time

At TFA, influent PCE concentrations have been reduced from about 900 ppb to <100 ppb since startup.

Influent Contaminant Mass Removal

Information on the total volume of VOCs removed by each treatment facility has only recently been collected as the facilities have become fully operational. From start of operation through August 1995, mass removal has been:

Treatment Facility	VOC mass removed (kg)	Extracted ground water (Mgal)	Average extraction rate (gpm)
TFA	56	151	200
TFB	11	29	50
TFC	3.1	6.8	22
TFD	4.9	1.6	8
TFF	*10,200	1.6	50

* Gallons of liquid equivalent gasoline

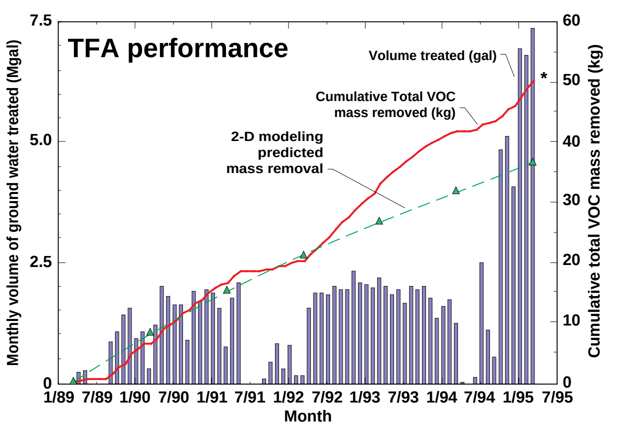


Figure 11. Cumulative mass removal of VOCs at TFA over time. Since 1992 TFA has consistently treated VOCs in ground water at a higher rate than that predicted by 2-D modeling.

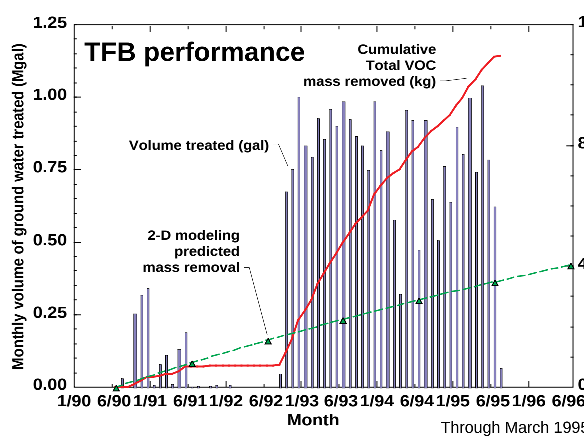
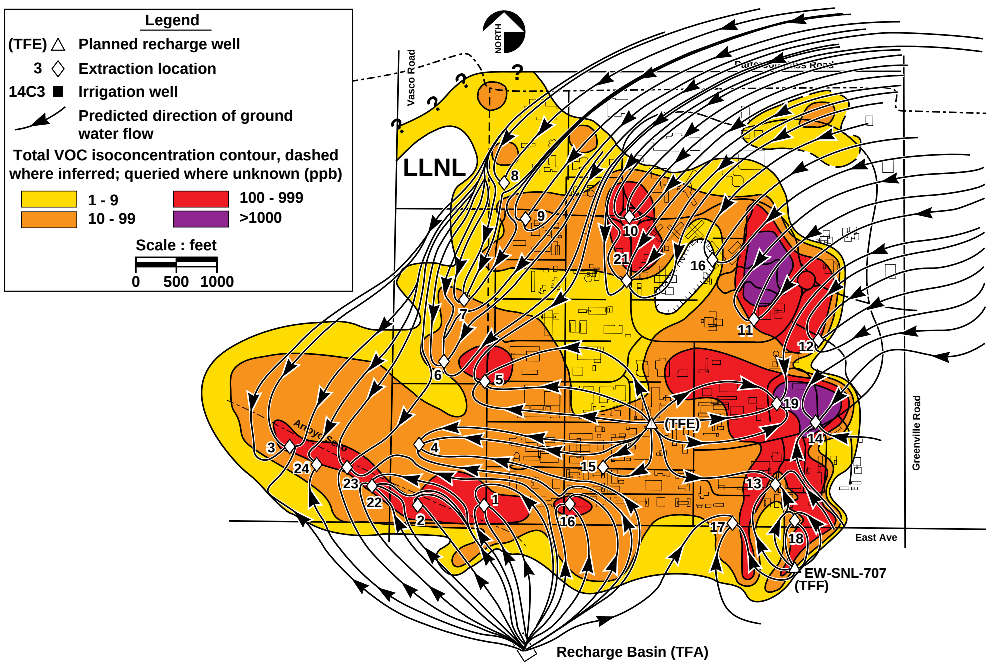


Figure 12. Cumulative removal of VOCs at TFB over time. Since June 1992 TFB has also treated VOCs in ground water at a significantly higher rate than that predicted by 2-D modeling.

Hydrodynamic Performance

TFA and TFB have now established hydraulic control over most of the western offsite portion of the VOC plumes (Figures 4-7). Modeling efforts anticipate the creation of complete hydraulic capture when all treatment facilities are fully operational.

Figure 13. Map showing predicted hydraulic capture zones and recharge well locations for the 24 initial extraction locations specified in the Record of Decision using 2-D modeling.



COST

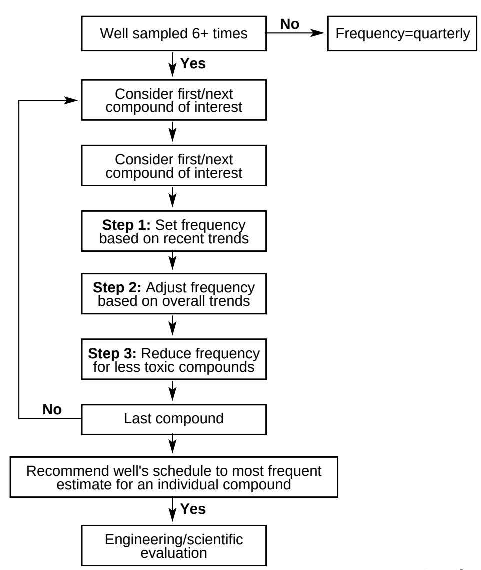
Operating and Capital Costs

Facility	Capital (K$)*	Operating (K$/yr)
TFA	896	500
TFB	446	400
TFC	1,628***	450
TFD	1,589***	470
TFE	1,516**	470
TFF	2,530	480

* Capital costs do not include well installation or all pipelines
** TFE fixed treatment facility cost. This may be replaced with PTU's.
*** Includes ion exchange unit for metals

Cost Effective Sampling

- Cost-Effective Sampling (CES) is a new method developed at LLNL for estimating the lowest-frequency sampling of monitor wells for remedial and compliance-related decision making.
- Statistical analysis provides trends and outliers observed in the sampling. These data yield essential compliance information with fewer samples. CES is also being used at Savannah River Site and is under consideration by other DOE sites.
- CES has resulted in a 50% reduction in the number of samples taken for analysis for volatile organic compounds from monitor wells at the Livermore Site.



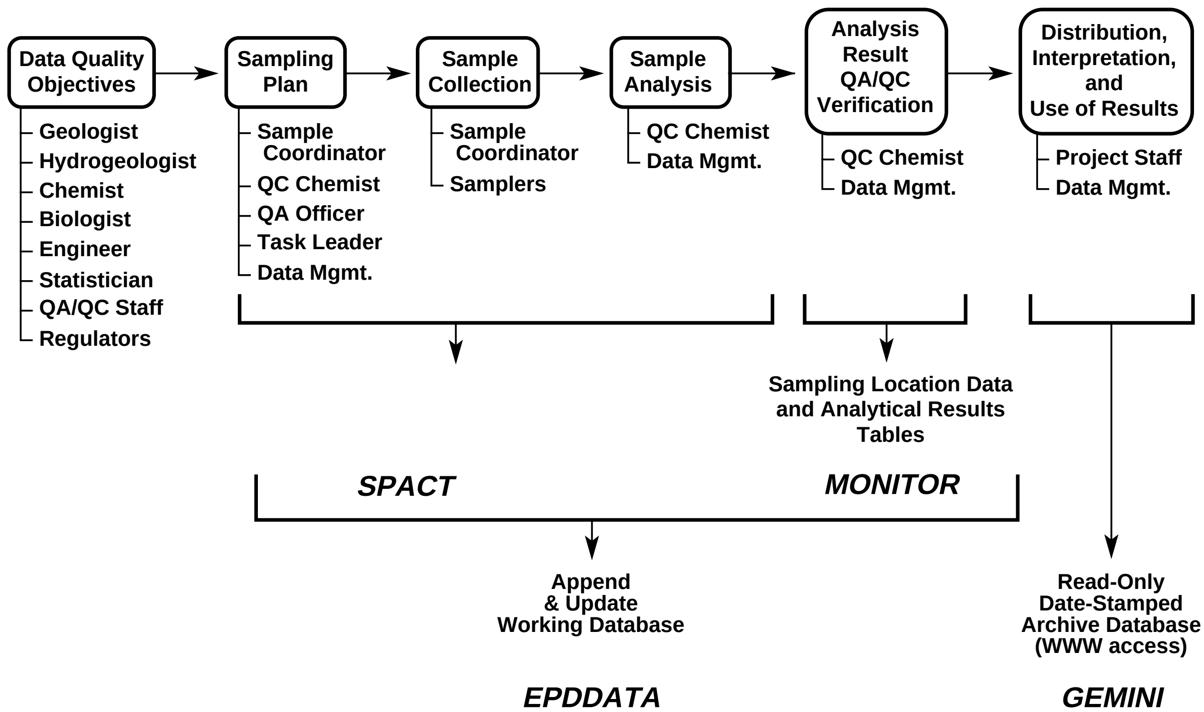
CES views the need for sampling in terms of the rate at which change is occurring in the measured concentrations of contaminant in an individual well, tempered by the degree of uncertainty associated with the change. Rates of change are translated into broad scheduling categories: quarterly, semiannual, and annual. Variability is combined with rate of change information to increase the frequency of scheduling when uncertainty is high. An early version of CES was implemented at LLNL in 1992 and subsequently approved by local regulatory agencies.

Data and Information Management

- The Data and Information Management Group (DMG) of the Environmental Restoration Division at LLNL provides integrated sample and data management services that support planning, collection, tracking, verification, validation, reporting, interpretation and use of data produced in characterization, remediation, self-monitoring, and surveillance monitoring.

- This system has been in use at LLNL since 1986. Over 130,000 samples, 1.7 million analytes, and descriptive information, geographic coordinates, for over 8800 sampling locations are included in the system. Approximately 2000 sample records are added each month.

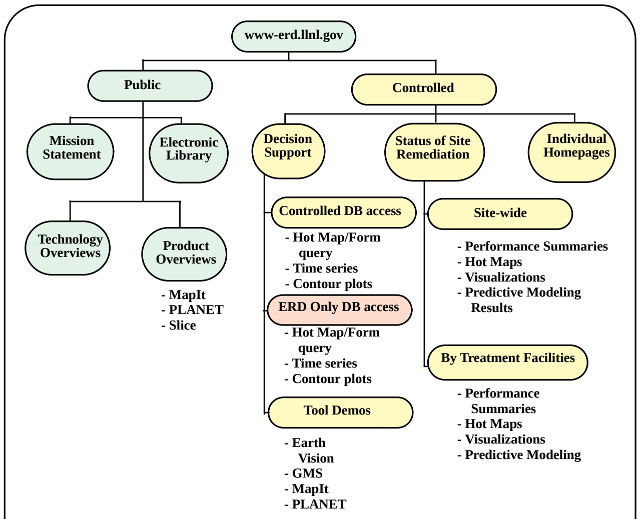
Data and Information Management



The DMG software tools are linked to the World Wide Web database access, have decreased labor-intensive overhead in the site study, and have increased the efficiency of the Ground Water Project.

ERD and the World-Wide-Web

ERD has developed innovative new uses of the emerging world-wide-web (WWW) technology. In addition to the traditional use of providing access to static documents, reports, images, and product and technology overviews, our webserver also provides division personnel and DOE with dynamic access to project status by allowing form-based statistical processing, database access, and cost estimating tools. These new capabilities have demonstrated significant cost savings and, for the first time, have made the enormous amount of collected data available to scientists on their desk top in a timely fashion and in a form immediately useful.



Organization of Environmental Restoration Division World-Wide-Web Server.

LLNL Environmental Restoration Division Home Page as shown on the WWW server can be accessed using *http://www-erd.llnl.gov*

Modeling/Visualization

Ground water Modeling

Modeling contaminant transport fulfills several project needs to:

- Estimate future VOC concentrations and risk to human health and the environment
- Optimize remedial design to save time and money
- Provide insight to complex systems
- Evaluate effects of source areas

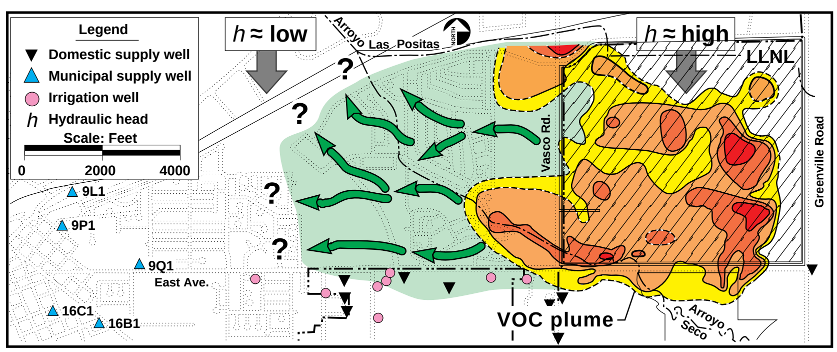


Figure 14. Contaminants migrate to high risk receptors at uncertain rates and along unknown pathways

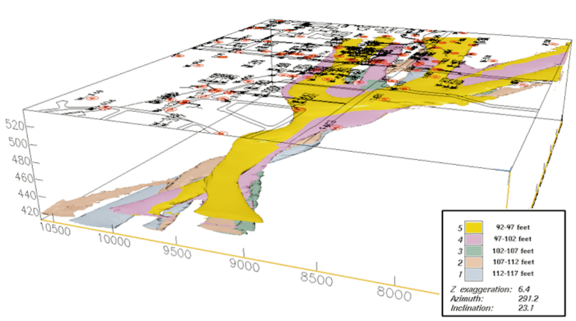
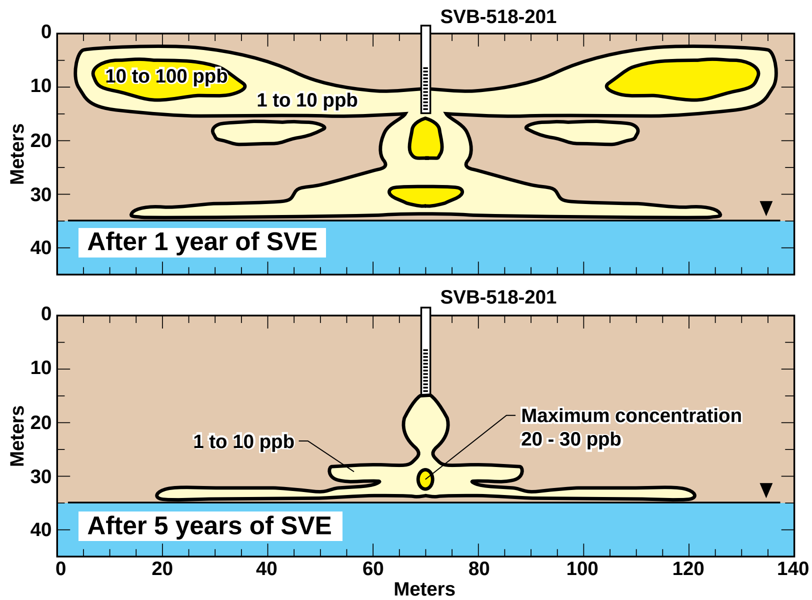


Figure 15. LLNL developed a sophisticated three-dimensional visualization software called SLICE which allows hydrogeologists to increase their understanding of contaminant distribution and potential migration pathwys. Once constructed, these "models" provide input to highly-detailed, predictive, numerical fate and transport models, and aid in placement of extraction and monitor wells.

Modeling/Vadose Zone

Vadose zone analysis is key to remediation efforts in the source areas. Multiphase modeling of the heterogeneous subsurface determines potential impacts of vadose zone sources on the ground water. Modeling it is also used to determine remedial system configurations and capacities.

Figure 16. The LLNL-developed vadose zone model, NUFT was used to simulate vadose zone remedial action by soil vapor extraction for the Building 518 Area Remedial Design document. As shown, results indicate that five years of soil vapor extraction should minimize impacts of VOCs in the vadose zone on ground water.



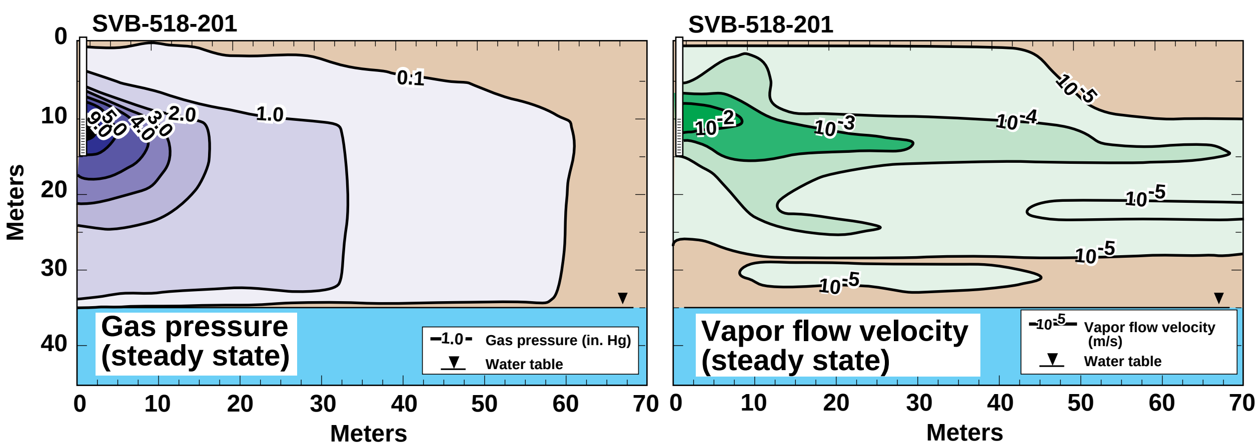


Figure 17. This figure illustrates that modeled soil vapor velocities are a better indicator of remediation performance than conventional pressure estimates in heterogenous media under induced vacuum.

Regulatory/Institutional Issues

• All treatment facilities comply with the Bay Area Air Quality Management District standards for VOCs. Ground water discharges to the storm sewer are controlled by National Pollutant Discharge Elimination System (NPDES) requirements (currently TFB, TFC and TFD). Ground water discharges to the LLNL Recharge Basin are controlled by the San Francisco Bay Regional Water Quality Control Board (RWQCB) Waste Discharge Order Requirements (currently TFA). Ground water discharge to the sanitary sewer is controlled by Livermore Water Reclamation Plant (LWRP) requirements (currently TFF).

• An active and ongoing public involvement program conducted through the Livermore Valley Community Work Group (CWG) has served to coordinate discussions and commentary from the interested local population.

• An extensive and detailed quantitative risk assessment involving contaminant fate and transport modeling was performed for the Livermore Site. The “best estimate” of noncarcinogenic risk produced a Hazard Index (HI) of 1.6E-3 indicating little potential for chronic health effects. However, an EPA health conservative (worst case) risk assessment method produced cancer risks as high as 1E-3 and HI's equalling 1, which exceeds EPA's acceptable cancer risk range at Superfund sites of 1E-4 to 1E-6 and indicates the potential for chronic health effects. The best estimate of the maximum incremental risk of developing cancer was 2E-7 from a lifetime exposure to VOCs in downtown Livermore well water. No members of the public are currently exposed to VOCs from the use of water-supply wells near LLNL.

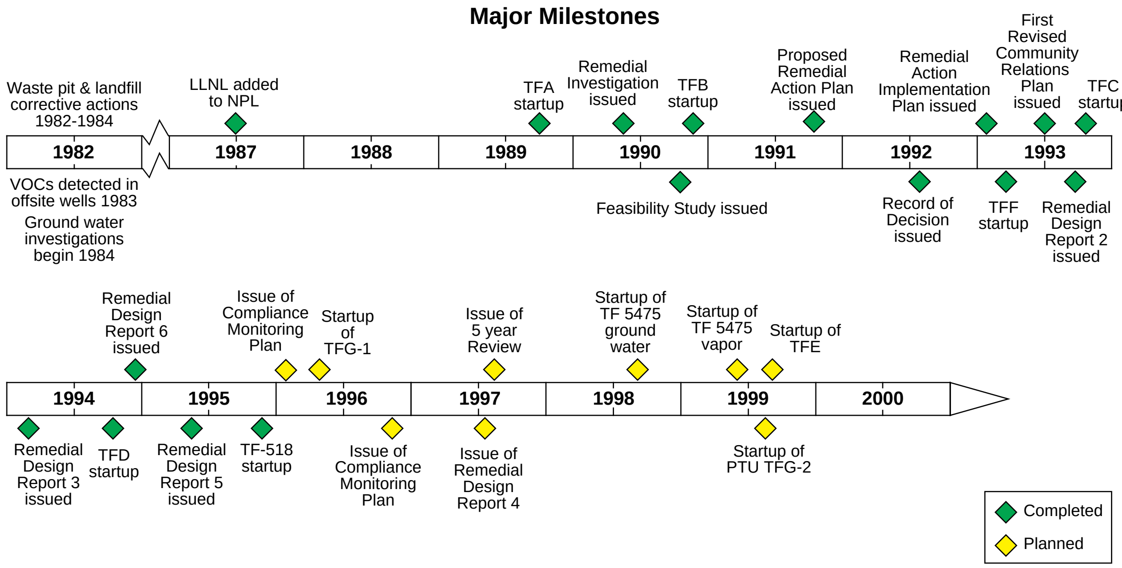
• Successful interactions with regulatory agencies include: (1) renegotiated project milestones for efficiency and cost effectiveness (2) negotiated reduced reporting requirements (3) negotiated approval to install downgradient extraction systems to ensure hydraulic control of offsite plumes (4) modified the Record of Decision based on regulatory acceptance of an Explanation of Significant Difference, and (5) received regulatory decisions of closure and No Further Action for fuel hydrocarbons in the vadose zone and saturated zone, respectively, at TFF.

Cleanup Criteria

Currently, treatment systems will be operated until ground water concentrations of target contaminants are below MCLs for two years. Site monitoring, reporting, and closure will be discussed in the upcoming Compliance Monitoring Plan (currently in review and comment phase).

Schedule

The chronology of events in the LLNL Livermore site environmental cleanup is shown below.



ENVIRONMENTAL RESTORATION SUMMARY

Accomplishments

• The LLNL ground water pump and treat remediation system is effectively capturing and remediating the western margin offsite plumes and accelerating ground water cleanup.
• Advanced characterization methods using hydrostratigraphic analysis are optimizing placement of extraction wells to maximize contaminant mass removal rates and provide hydraulic control of plumes. The methodology is cost-effective in light of the high cost of unnecessary or misplaced wells.
• Renegotiation of CERCLA milestones with State and Federal regulators has reduced costs and enhanced cleanup. This includes negotiating site closure under the Containment Zone (CZ) and Technical Infeasibility (TI) guidelines of the TFF area vadose zone. Steam injection during the Dynamic Stripping Demonstration Project greatly accelerated the removal of fuel hydrocarbons at this location.
• LLNL-designed and constructed treatment facilities are successfully treating VOCs in ground water by UV/oxidation and air stripping and metals by ion-exchange.
• The LLNL-designed integrated data and information management system allows for quick access to characterization and remediation information needed for cost-effective decision support.
• Cost-effective sampling techniques developed at LLNL have resulted in a 50% reduction in the number of ground water samples collected from monitor wells for VOC analysis.
• Effective use of the World Wide Web (WWW) is allowing for rapid access and analysis of data to evaluate hydraulic capture, contaminant trends, and data validation. This allows critical remedial decisions to be made in minutes rather than weeks.

Lessons Learned

• The HSU characterization methodology has allowed LLNL to develop a site-wide working hydrogeologic model necessary for targeting specific contaminant plumes and leading to accelerated VOC mass removal and optimization of the cleanup.
• Advanced 3-D ground water and vadose zone fate and transport modeling techniques developed at LLNL allow for in-depth analysis of various regulatory cleanup objectives and remedial alternatives.
• Carefully planned, phased implementation of treatment facilities has allowed the project to optimize remedial actions and meet cleanup objectives.
• Integration of hydrogeologic modeling with engineering design was essential for implementing the LLNL site clean up plan in a cost-effective manner.
• Conducting pilot-scale and field demonstrations proved useful in the design and construction of effective treatment systems.
• The deployment of portable treatment units (PTUs) allows project managers to adapt to changes in ground water and vadose zone conditions due to ongoing plume migration and/or changes in contaminant concentrations. This results in lower costs than are required for a fixed treatment system.
• The Livermore Valley Community Work Group (CWG) was established to maintain a high level of community and regulatory communication and understanding of project goals and objectives. LLNL personnel share all data and discuss work-in-progress with regulators and the community during monthly and quarterly scheduled meetings as well as at seminars and workshops convened on an as-needed basis. This approach has secured early concurrence from the regulatory agencies and the public during ongoing technology-related decision making.

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